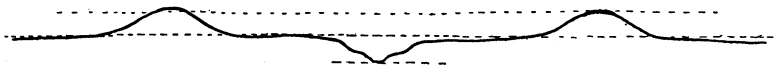
MOUNTAIN STRUCTURES OF PENNSYLVANIA.

BY

A. P. CHITTENDEN.

Hitherto it has commonly been considered, and is even stated by the text books, that synclinal mountains are the predominant type in regions where the folded rocks have been deeply denuded. But during the last few months, the mountains of the Appalachian District of Pennsylvania have been studied with some care; and the writer has come to an opinion concerning their structural character that is at variance with the belief hitherto held. The following paragraphs contain a synopsis of the conditions of these mountains and of the explanation of their origin and forms.

Professor Davis * shows that the mountains in Pennsylvania consist of a series of ridges rising above a plain, below the level of which are the valleys dissected by rivers. This relation of parts is seen in Figure 1.



Dana, after speaking of the steps in the formation of the Appalachian Mountain Range, says, under the heading "The Relations of Mountain-ranges to Denudation," † "Carving, gouging and levelling through denudation, go on very rapidly in elevated regions of even a moderate amount of rain, and have gone on through long ages, since the rocks were made, so that the original forms of the anticlines and synclines of mountain ranges have disappeared, generally leaving ridges where synclines once existed. . . . . The greater valleys are made along anticlynes because of the profound longitudinal fracturing of their summits in consequence of the tension produced by the upward bending of the strata. This leaves the intervening synclinal belt as the course of the mountain ridges."

Sir Archibald Geikie treats the subject as follows: ‡ Speaking of

* "Rivers and Valleys of Pennsylvania."—Sketches.

† Dana, Manual of Geology, 4th Ed., p. 387.

‡ Text Book of Geology, p. 1022.

flexures, he illustrates the differences of inclination by the Jura and the Appalachians, and says: "It will usually be observed that the surface of the ground does not strictly conform for more than a short distance to the surface of any one bed; but that on the contrary it passes across the edges of successive beds. This relation—so striking a proof of the extent to which the surface of the land has suffered from denudation—may be followed through successive phases, until the original superficial contours are exactly reversed, the ridges running along the lines of syncline and the valley along the lines of anticline. Among the older rocks of the earth's crust, which have been exposed alike to curvature and prolonged denudation, this reversal may be considered to be the rule rather than the exception." Geikie's diagram, referred to in this connection, is a section across the folded rocks of the Appalachian Chain, in which the synclinal ridges are represented as predominant.

Influenced by these writers, as authorities, Hinman, in his school book, Eclectic Physical Geography, carries the idea still further. It is to be noticed also that this part of his work stands under the approval of Dutton. Hinman first explains very well in what manner the crests of folded strata are worn down more rapidly than the troughs, and leads up to the point that in the older mountains, such as the Appalachians, this process has gone on so far that one would reasonably expect the occurrence of the present ranges along the troughs of the original folds. In his own words: "In younger mountains, such as the Jura, the tops of the folds have not yet been so greatly lowered, but by the time they have suffered erosion as long as the Appalachians, the present position of mountains and valleys will have been reversed."

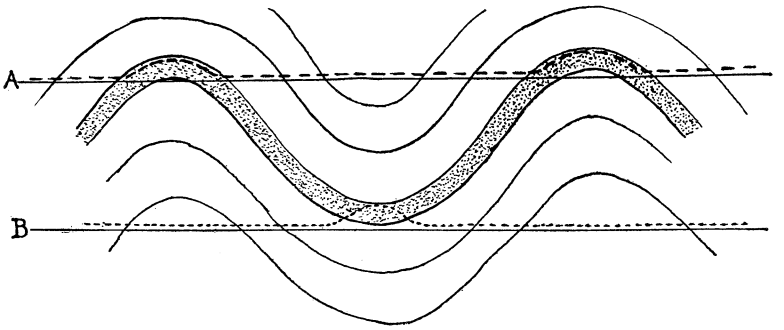
Ralph S. Tarr, speaking of old mountains, or folds which have undergone much denudation, says:* "In these low and much-worn mountains the more elevated parts are always those of hard rocks, while most of the large valleys are situated in the layers of soft strata. In such cases, and in fact even before denudation has proceeded so far, anticlines, which were originally mountains, are often worn down to valleys and synclinal valleys are transformed to mountains. Not only is this true here [in the old hills of Connecticut, Rhode Island and Massachusetts], but many of the Appalachian ranges are synclines."

From these illustrations from authorities it is clear that the prevailing opinion is that it is quite the proper thing that erosion should produce synclinal mountains and anticlinal valleys.

* Elementary Geology (1897), p. 309.

Let us look at the process of land sculpture more in detail, however, in a folded region such as the Appalachians.

The ultimate form of land sculpture is, of course, the base-level plain. Whatever its structure, every surface must be reduced to this level, if time be allowed,—and this constitutes its final form. But is it essential, as the writers mentioned would have us suppose, that in the late forms assumed in the process of base-levelling, there should be synclinal mountains and anticlinal valleys? The chief factors in determining the mountain structure are:—*the altitude of base-level, the resisting powers of the structure, and the time and stage of dissection.** Thus to produce a synclinal mountain it is requisite that the position of base-level be just below the level of the trough formed by the hard beds. This relation of base-level to structure is seen by the diagram (Fig. 2), where B is the base-level, and the



dotted stratum is the hard bed. Here the quick erosion, afforded on the lower soft beds, which are discovered by the breaking of the anticlinal crests, will soon cause the chief water-courses to abandon the synclinal axes they had before followed, and excavate valleys along the axes of the anticlines. As a result, the late form, represented by the dotted lines, will consist of an inversion of the original structural surface.

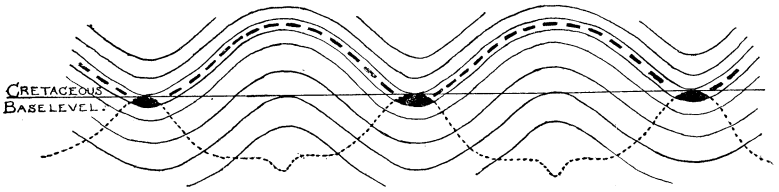
But suppose the base-level to be at A, a little below the arches of the hard bed. It is evident that the late forms resulting from erosion will consist of broad synclinal lowlands, between anticlinal ridges, as indicated by the broken line.

A position of base-level, however, would be more likely to occur somewhere between A and B. Let us look now at the geology of Pennsylvania, a field structurally better suited to the inquiry than any other part of the Appalachians, and see if this more natural

* W. M. Davis; Science, XII, 320.

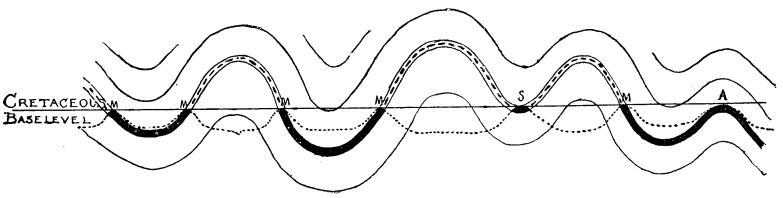
occurrence of base-level in relation to structure exists. The folding that produced the mountains took place in pre-Triassic times. In Cretaceous time, the region was then base-levelled, the last remnant of which we see now in the general level of the present ridges. Finally, Tertiary and later excavations have brought into relief those parts which had a capping of hard strata close below the Cretaceous base-level. In other words, wherever the hard strata (of Medina, Pocono and Pottsville age) came to the surface of the Cretaceous base-level plains, we have ridges or plateaus.

Such is the history of the region, and it is evident that only by mere chance could the base-level cut the troughs of the hard strata as shown in Figure 3.



(The hard stratum is here represented by black; and the dotted line indicates the present surface, which has been lowered from the Cretaceous base-level chiefly by Tertiary excavations.)

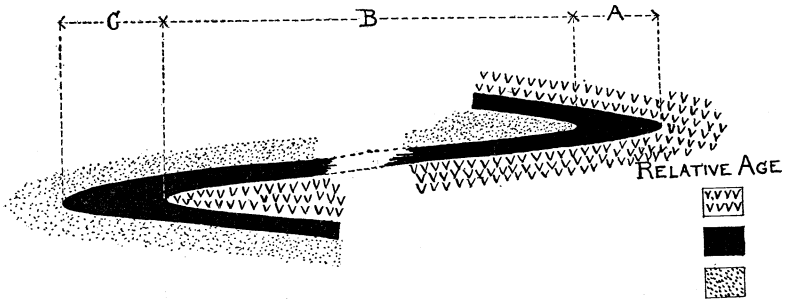
It is evident that this is a most special and fortuitous case (a most ideal thing), and yet synclinal mountains cannot be the prevailing type under any other conditions. We would naturally expect the relation of base-level to the folds of the hard strata, as expressed by Figure 4, to be much more likely to occur.



In such a case if we agree to call mountains of the structure M, monoclinal or isoclinal mountains, it is evident that Tertiary excavations below the level of the Cretaceous plain would reveal monoclinal mountains as the general structure, and that synclinal (S) or anticlinal (A) mountains would be but of occasional occurrence.

Thus from a reasonable study of the history of the Pennsylvania region, we could safely object to the before-mentioned opinions regarding the structure of these mountain forms. In addition, the

prevalence of the different mountain types of Pennsylvania has been determined by measurements, made from the geological map by J. P. Lesley, 2d Pa. Survey. The number of miles of synclinal, anticlinal and monoclinal mountains has been obtained, the terms being applied as shown in Figure 5.

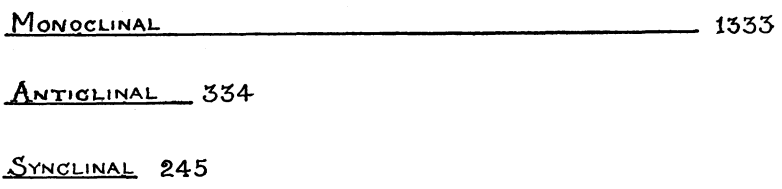


The black is the hard stratum, or ridge-maker, and the portion of its outcrop, A, is considered an anticline, the part B a monocline, and the part C a syncline. Wherever the Medina sandstone, or the Pocono sandstone, and to a certain extent the Pottsville conglomerate outcrop, mountains occur. As a rule, all the outcrops measured are recognized as mountain ridges under local names, as shown in the text of the description of counties, even where the outcrops in their close turns are very near together.

The Medina has 1,200 miles of outcrops. Of these 756 miles are monoclines, 271 miles are anticlines, and 173 miles are synclines. Of the Pocono, 436 miles outcrop in the form of ridges, of which 359 are monoclines, 45 are anticlines, and 32 are synclines. The Pocono and Pottsville form ridges together to the amount of 69 miles, of which 64 miles are monoclinal and 5 miles synclinal. The Pottsville has 202 miles of outcrops as mountains, 149 miles being monoclinal, 35 miles synclinal, and 18 miles anticlinal. But in the coal region, the Pottsville mountains of monoclinal structure are not so definitely marked off from one another as the Medina monoclinals of other portions of the State. The larger portions of the high-ground areas of the coal region are unquestionably of synclinal structure; but those parts, which, as a rule, are recognized as the mountains, are prevailingly monoclinal, as the figures show.

The outcrops at the edge of the Alleghany Plateau, at Laurel Hill, Chestnut Ridge, Pocono Plateau, and Broad Top, have not been considered, as they do not properly belong to the type of mountains.

Represented graphically, the predominance of structure in the Pennsylvania Appalachians is clearly shown in Figure 6.



The possible limit of error in the measurements, shown by the lowest line, can do nothing to change the relation of these lines to one another.

This result of facts is really only what we could expect were we to consider the case from the point of view of the base-level. The synclinal mountain is *not* a necessary or even a general result, and is far from being the prevailing type of mountains due to denudation in this district. In connection with the factor of time, the mountain forms obtained are simply the result of the accidental position of hard beds in relation to the controlling base-level.

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